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Corrosion of Mechanical
Seal Materials Induced by
Coupling to Carbon

Assignment 82 121
Phase II
MEL Research & Development Report 117/64

21 August 1964

By
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REFERENCE

(a) J. L. Basil, "Progress Report on Mechanical Seal Materials: Investigation of Corrosion," NAVENGRXSTA Rept 910167C of 17 Jun 1962

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ABSTRACT

THIS IS THE SECOND PHASE REPORT ON SEA-WATER CORROSION OF MATERIALS FOR USE IN MECHANICAL SEALS FOR SUBMARINE SHAFTING AND CONCERNS GALVANIC CORROSION EFFECTS RESULTING FROM COMBINATIONS OF METALS AND CARBON. SIX ALLOYS WERE SELECTED FOR TEST: A TIN BRONZE, A NICKEL-ALUMINUM BRONZE, A HIGH-COPPER ALLOY, TWO NICKEL-COPPER ALLOYS, AND A NICKEL-BASE ALLOY. GALVANIC CORROSION WAS DETERMINED FOR EACH ALLOY, COUPLED TO EACH OF THREE GRADES OF CARBON. RESULTS SHOW SUBSTANTIAL GALVANIC CORROSION OF FIVE ALLOYS. THE EXCEPTION WAS THE NICKEL-BASE ALLOY, WHICH EXHIBITED ESSENTIALLY NO ATTACK IN EITHER COUPLED OR UNCOUPLED TESTS.

ADMINISTRATIVE INFORMATION

Investigation of the fundamental aspects of the corrosion behavior of seal materials was originally authorized by Bureau of Ships letters 9340/1, Serial 644-989 of 9 December 1960 and 9430/1 F013 07 01, Serial 644-647 of 26 September 1961. The work has been continued under Subproject S-F013 07 01, Task 3724.

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CORROSION OF MECHANICAL SEAL MATERIALS INDUCED BY COUPLING TO CARBON

1.0 INTRODUCTION

THE U. S. NAVY MARINE ENGINEERING LABORATORY IS ENGAGED IN AN EXTENSIVE INVESTIGATION OF MECHANICAL SEALS FOR DEEP-SUBMERGENCE SUBMARINES. ONE SEGMENT OF THE INVESTIGATION IS CONCERNED WITH THE SPECIAL CORROSION PROBLEMS WHICH CAN OCCUR IN MECHANICAL SEALS. THESE PROBLEMS ARISE FROM THE NEED FOR A VARIETY OF MATERIALS TO PERFORM SPECIFIC FUNCTIONS. IN A SEA-WATER ENVIRONMENT, THE COMBINATION OF MATERIALS CAN LEAD TO ACCELERATED CORROSION OF SOME COMPONENTS BY GALVANIC COUPLING TO OTHER COMPONENTS MADE OF MORE NOBLE MATERIALS.

AT THE OUTSET OF THE INVESTIGATION, EIGHT ALLOYS, SIX GRADES OF CARBON, AND SEVERAL TYPES OF HARD-SURFACING MATERIALS WERE SELECTED FOR STUDY. THE CORROSION BEHAVIOR OF THE EIGHT ALLOYS IN GALVANIC AND CREVICE-CORROSION TESTS HAVE BEEN REPORTED, REFERENCE (A). THIS REPORT CONCERNS THE GALVANIC EFFECTS OF COUPLING SIX OF THE METALS INDIVIDUALLY TO THREE GRADES OF CARBON. CORROSION TESTS INVOLVING THE HARD-SURFACING MATERIALS HAVE ALSO BEEN MADE AND WILL BE REPORTED AT A LATER DATE.

2.0 MATERIALS

THE NOMINAL COMPOSITIONS OF THE SIX ALLOYS WHICH WERE COUPLED TO EACH OF THREE GRADES OF CARBON ARE PRESENTED IN TABLE 1.

Table I

Nominal Composition of Materials Subjected to Galvanic Corrosion Tests

MEL Code	Material	Specification	Cu	Al	Fe	Ni	-	-	-
DSR	M Bronze	QQ-C-525, Comp 1	87.5	-	0.20 (a)	0.75 (a)	Sn 6.0	Zn 4.0	Pb 1.4
DSS	Ni-Al Bronze (c)	QQ-B-675, Class 4	82.0	11.0	2.7	4.2	Mn 0.05	-	-
DSZ	Cupalloy 7550		Rem	-	-	-	Cr 0.4-1.0	Ag 0.08-0.12	-
DSX	H Monel	QQ-N-228, Comp B	30.0	-	2.50 (a)	64.5	Mn 1.5 (a)	Si 3.2	-
DSY	S Monel	QQ-N-228, Comp D	29.5	-	2.50 (a)	60.0 (b)	Mn 1.5 (a)	Si 4.0	-
HC	Hastelloy C		-	-	5.0	59.0	Mo 16.0	Cr 16.0	W 4.0

(a) Maximum (b) Minimum (c) MEL Analysis

3.0 METHOD OF TEST

THE METHOD OF CONDUCTING THE GALVANIC CORROSION TESTS WAS DESCRIBED IN DETAIL IN REFERENCE (A). THE GALVANIC CELLS, SHOWN SCHEMATICALLY IN FIGURE 1, WERE MADE OF HARD RUBBER PROTECTED BY A BRASS CASING. TWO SPECIMENS (ONE METAL AND ONE CARBON) WERE SECURED IN EACH CELL AS SHOWN. SEAWATER FLOWED BETWEEN THE SPECIMENS WHICH WERE ELECTRICALLY CONNECTED THROUGH A LOW RESISTANCE EXTERNAL SHUNT. THE VELOCITY OF THE SEAWATER WAS MAINTAINED AT 13 FT PER SEC DURING THE 62 DAYS OF TEST. * THE METAL AND CARBON SPECIMENS HAD EXPOSED AREAS OF 2.625 SQUARE INCHES EACH.

4.0 RESULTS OF TEST

WEIGHT LOSSES AND CORROSION RATES OF THE SIX ALLOYS COUPLED AND NOT COUPLED TO THREE GRADES OF CARBON, ARE PRESENTED IN TABLE 2. CORROSION RATES ARE REPORTED AS MILLIGRAMS PER SQUARE INCH PER DAY (MDD) AND INCHES PENETRATION PER YEAR (IPY). THE GALVANIC EFFECT REPORTED IN COLUMN 5 IS THE DIFFERENCE BETWEEN THE CORROSION RATE OF THE CONTROL (NOT COUPLED) AND THE COUPLED SPECIMENS. THE MAGNITUDE OF THE GALVANIC EFFECT IS ILLUSTRATED IN FIGURE 2, A BAR GRAPH OF CORROSION RATES.

4.1 <u>CATHODIC ACTION</u>. THE BAR GRAPH AND TABLE 2 INDICATE THAT THE THREE GRADES OF CARBON ACTED AS STRONG CATHODES TO ALL MATERIALS EXCEPT HASTELLOY C. THE CORROSION RATE OF THIS ALLOY WAS THE SAME WHETHER COUPLED OR NOT COUPLED TO THE CARBONS. CORROSION RATES OF THE OTHER ALLOYS WERE INCREASED SEVERAL-FOLD BY GALVANIC ACTION. RATIOS OF THE CORROSION RATES OF COUPLED SPECIMENS TO RATES OF NONCOUPLED SPECIMENS ARE SHOWN IN COLUMN 6. THESE RATIOS SHOW THAT THE CATHODIC CHARACTERISTICS OF EACH OF THE THREE GRADES OF CARBON WERE ABOUT THE SAME WHEN COUPLED TO NICKEL-ALUMINUM BRONZE, CUPALLOY, S MONEL, AND HASTELLOY C. (THE LOW RATIO FOR THE S MONEL: CARBON 72J COUPLE IS ATTRIBUTED TO LOSS OF CONTACT BETWEEN THE SPECIMENS WHEN THE CARBON SAMPLE BROKE SOMETIME DURING THE TEST.) WHEN COUPLED TO G BRONZE AND TO H MONEL, THE CATHODIC BEHAVIOR OF THE CARBONS WAS SOMEWHAT IRREGULAR, WITH AT LEAST ONE GRADE OF CARBON PERFORMING AS A COMPARATIVELY WEAK CATHODE.

4.2 <u>NO CARBON DETERIORATION</u>. SPECIMENS OF THE THREE GRADES OF CARBON, AFTER CLEANING AND DRYING, SHOWED A SLIGHT INCREASE IN WEIGHT (0.012 TO 0.100 GRAMS) WHETHER OR NOT THEY HAD BEEN COUPLED TO METAL SPECIMENS DURING THE TEST. THERE WAS NO VISIBLE EVIDENCE OF DETERIORATION OF THE CARBON SPECIMENS.

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* ABBREVIATIONS USED IN THIS TEXT ARE FROM THE GPO STYLE MANUAL, 1959, UNLESS OTHERWISE NOTED.

Table 2

Galvanic Corrosion of Metals Coupled to Carbons in Sea Water Flowing at 13 Feet per Second for 62 Days

Column 1		2	3	4	5	6
Coupled Materials (1)		Metal Weight Loss Grams	Metal Corrosion Rate		Galvanic Effect(3)	Ratio Coupled to Non-coupled Corrosion
Electrode A Metal	Electrode B Carbon		MDD	IPY	IPY	
G Bronze	(2) -	0.868	82.8	0.013	0	1.0
G Bronze	Grade 61A	5.439	519.0	0.085	0.072	6.5
G Bronze	Grade 14G	4.928	470.0	0.077	0.064	5.9
G Bronze	Grade 72J	1.527	146.0	0.024	0.011	1.9
Ni-Al Bronze	(2) -	0.171	16.3	0.003	0	1.0
Ni-Al Bronze	Grade 61A	1.509	144.0	0.027	0.024	9.0
Ni-Al Bronze	Grade 14G	1.530	146.0	0.027	0.024	9.0
Ni-Al Bronze	Grade 72J	1.649	157.0	0.029	0.026	9.6
Cupalloy	(2) -	1.036	98.9	0.016	0	1.0
Cupalloy	Grade 61A	5.729	547.0	0.088	0.072	5.5
Cupalloy	Grade 14G	5.881	561.0	0.090	0.074	5.6
Cupalloy	Grade 72J	6.916	666.0	0.106	0.090	6.6
H. Monel	(2) -	0.098	9.4	0.002	0	1.0
H. Monel	Grade 61A	0.713	68.0	0.012	0.010	6.0
H Monel	Grade 14G	0.103	9.8	0.002	0.000	1.0
H Monel	Grade 72J	1.369	131.0	0.022	0.020	11.0
S Monel	(2) -	0.103	9.8	0.002	0	1.0
S Monel	Grade 61A	1.214	116.0	0.020	0.018	10.0
S Monel	Grade 14G	2.349	224.0	0.038	0.036	19.0
S Monel	Grade 72J	0.976	93.1	0.016	0.014	8.0
Hastelloy C	(2) -	0.005	0.48	0.0001	0	1.0
Hastelloy C	Grade 61A	0.005	0.48	0.0001	0	1.0
Hastelloy C	Grade 14G	0.005	0.48	0.0001	0	1.0
Hastelloy C	Grade 72J	0.005	0.48	0.0001	0	1.0

(1) Coupled through 0.01-ohm Resistor;
Specimen area 2.625 sq in
(2) Control - not coupled
(3) Galvanic effect - corrosion due solely to galvanic action

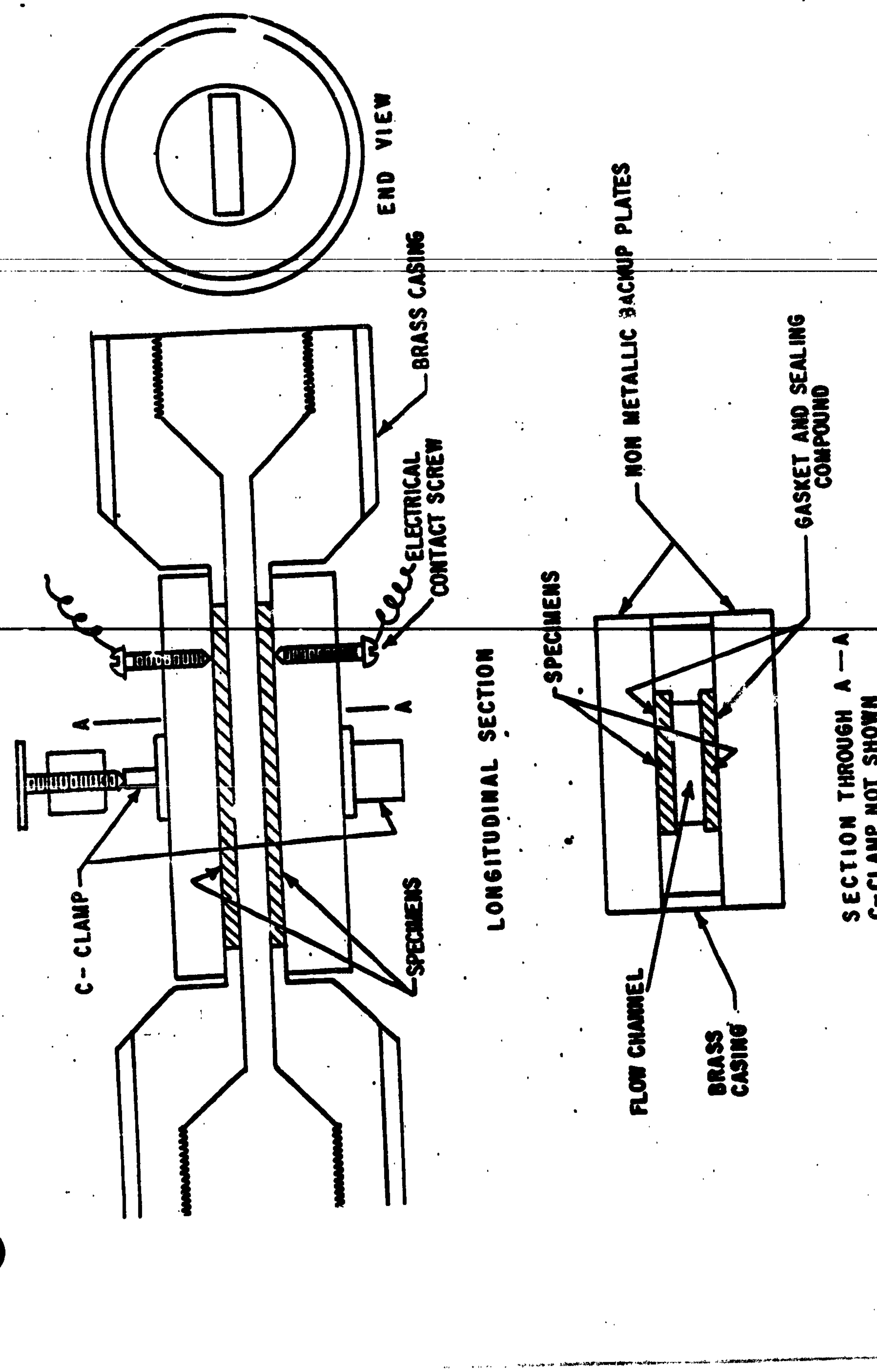

Figure 1 - Test Cell

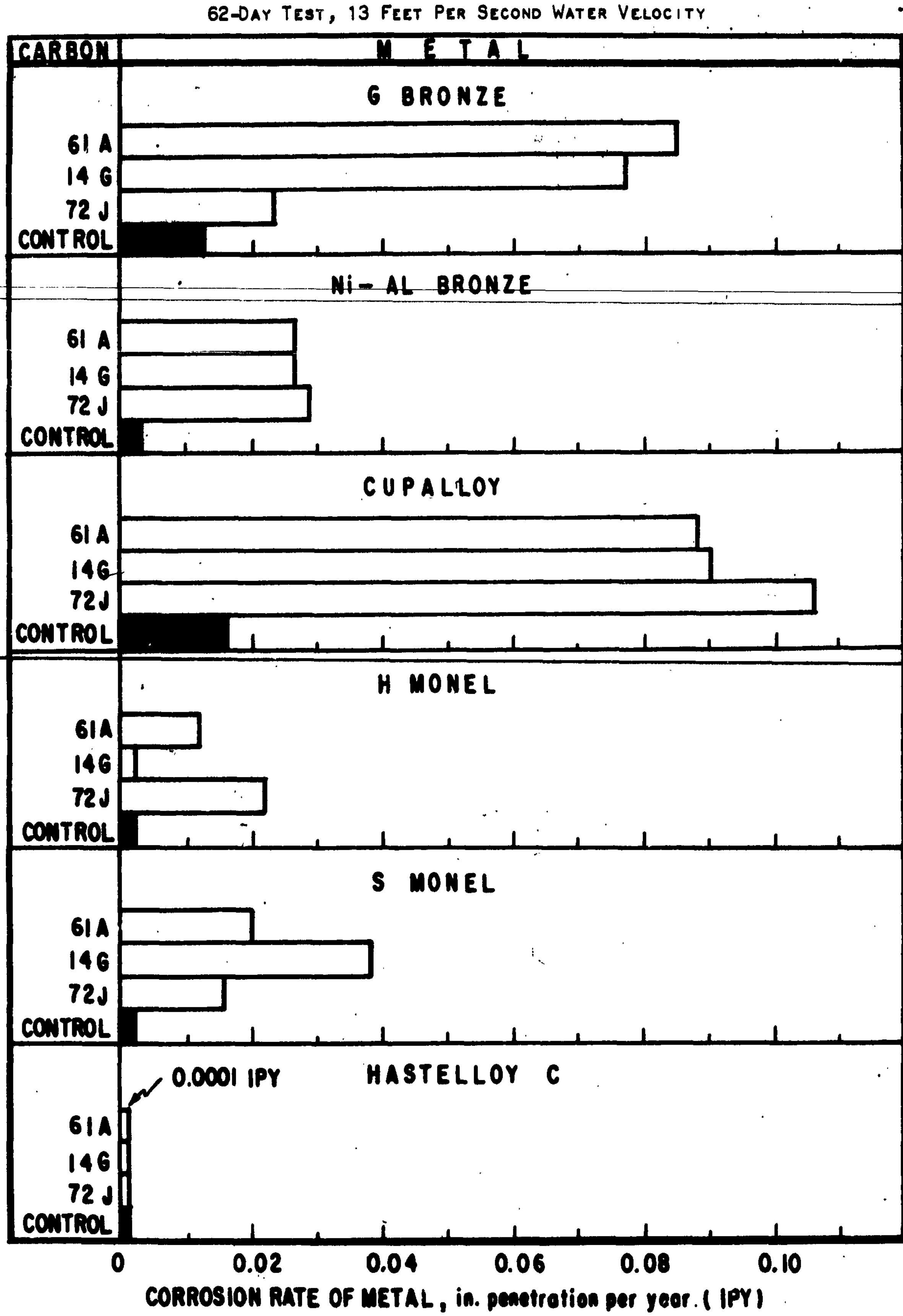

Figure 2 - Galvanic Corrosion of Metals Coupled to Carbons

5.0 DISCUSSION

The quality of the electrical coupling of the samples is an important factor in galvanic corrosion tests. Minor differences in the resistance of the circuit will markedly affect the current flow and the corrosion rate. In the results presented, the amount of scatter precluded differentiating among the three grades of carbon with respect to galvanic effect, or establishing a relationship between potential difference and galvanic corrosion. Despite these difficulties, the results demonstrated that substantial galvanic corrosion can develop in the coupling of carbons to metals (except Hastelloy C). The magnitude of the effect is attributed to the large difference in potential between carbon and metal as measured by a calomel half-cell.

5.1 Minimizing Galvanic Corrosion. In actual mechanical seals, the amount of carbon present is small relative to the surrounding metal. This provides a favorable area ratio between the cathode (carbon) and the anode (metal), as it promotes a situation that minimizes galvanic corrosion. However, the benefit of a favorable cathode-anode area ratio is dependent on polarization of the cathode. In the usual case, a small cathode area results in a high cathode current density; this favors polarization of the cathode, with resultant reduction of the galvanic current and galvanic corrosion of the anode. It is not known whether carbon is readily polarized. Without carbon polarization, it is possible to have significant corrosion of a metal in contact with the carbon, even though the amount of carbon is small.

5.2 Immune Specimen. The performance of Hastelloy C in the tests provided another example of the outstanding corrosion characteristics generally attributed to this material in seawater.. In the previous phase of the investigation, reference (a), it was shown that this material was essentially immune to crevice corrosion. Also, it was shown that, although Hastelloy C is a relatively noble material and can cause severe galvanic corrosion when coupled to some alloys, it causes little or no galvanic corrosion when coupled to the nickel-copper alloys or nickel-aluminum bronze. From these results, it seems apparent that combinations of materials can be selected for mechanical seals without introducing serious galvanic corrosion problems. One gap in the information, however, concerns the corrosion behavior of hard-surfacing materials. Corrosion tests of several types of these materials have been completed and will be reported as the third phase of the investigation.

6.0 CONCLUSIONS

On the basis of results presented, it is concluded that the three grades of carbon act as strong cathodes and can cause severe galvanic corrosion when coupled to equal areas of G bronze, nickel-aluminum bronze, Cupalloy, H Monel and S Monel. No galvanic corrosion is evident when Hastelloy C is coupled to carbon.